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Palaeomagnetism of a sequence of Upper Palaeozoic–Lower Mesozoic red beds from Argentina

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Summary. Palaeomagnetic data from 101 hand samples collected in a rock sequence of about 300 m of red beds and igneous rocks of the La Colina Formation (Late Palaeozoic) and Amaná–Talampaya Formation (Early Triassic) exposed in north-western Argentina (30° S 67° W) are given. Samples were submitted to thermal, chemical and AC cleaning.

After cleaning, the majority of La Colina Formation samples showed reversed polarity and yielded a palaeomagnetic pole at 49° S 343° E ($\alpha_{95} = 5°$), which is consistent with the K–Ar age (295 ± 5 Myr, Late Carboniferous) of a basaltic lava flow situated in the middle of La Colina rock succession. These rocks also recorded a normal polarity event (which we have correlated with the latest normal polarity event of the Debal'tseva Zone at the base of the Kiaman Magnetic Interval) and two excursions of the geomagnetic field.

After treatment, the samples from the Amaná–Talampaya Formation showed normal and reversed polarity and revealed frequent reversals and excursions of the geomagnetic field suggesting an Illawarra Zone age (post Kiaman, Late Tatarian–Early Scyntian and younger).

1 Introduction

In the north-western part of Argentina (Fig. 1) red beds and igneous rocks formed in Late Palaeozoic and Early Mesozoic time are exposed. These rocks have been classified heretofore in three subgroups within the Paganzo Group: a Lower Section (Paganzo I), a Middle Section (Paganzo II) and an Upper Section (Paganzo III). In a recent paper, Azcuy *et al.* (1978), have reclassified these rocks in two subgroups within the Paganzo Group and one formation.

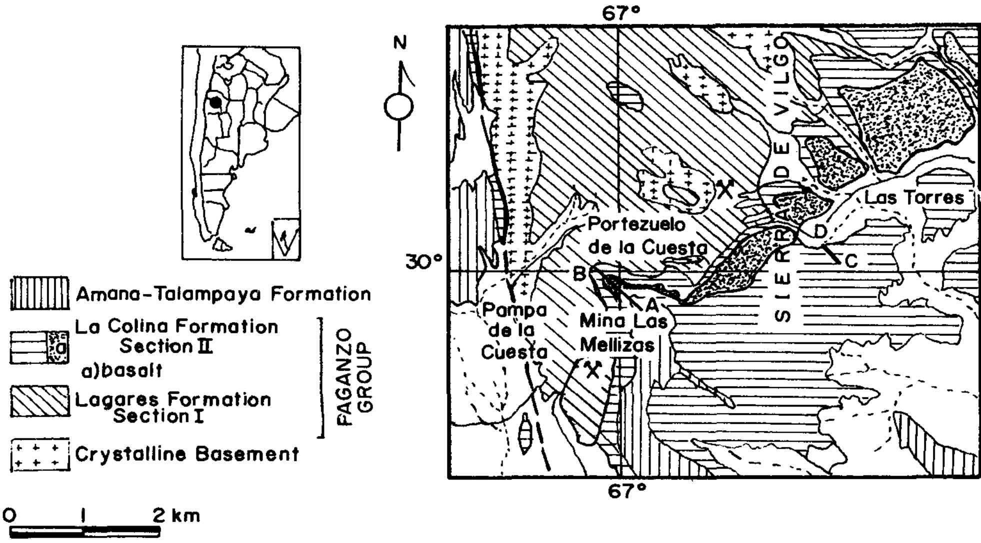


Figure 1. Schematic geological map of Paganzo Basin near Mina Las Mellizas (Azcuy & Morelli 1970) showing sampling profiles for the palaeomagnetic study.

Named in chronological order they are: Section I (Lower Section, Paganzo I) and Section II (Middle Section, Paganzo II) of the Paganzo Group and the Amaná–Talampaya Formation (formerly the Upper Section of Paganzo Group or Paganzo III).

The palaeomagnetic study of the red beds comprising the Paganzo Group and the Amaná–Talampaya Formation has been included in the Argentinian Programme for the Upper Palaeozoic of South America Project No. 42 of the International Geological Correlation Programme. Palaeomagnetic data of a sequence of red beds and igneous rocks from the Paganzo Group and the Amaná–Talampaya Formation collected near Paganzo village have been presented by Valencio, Vilas & Mendía (1977). The magnetic stratigraphy and the palaeomagnetic poles defined for this sequence were used to assign an age to the stable remanence of the rocks and for geological correlation.

We present here the results of a palaeomagnetic study of 101 hand samples collected from a sequence of about 300 m of red beds and igneous rocks of the Paganzo Group and the Amaná–Talampaya Formation exposed near Mina Las Mellizas (Sierra de Vilgo), 37 km to the north-west from Paganzo village. These palaeomagnetic data are used to correlate the rocks of this sequence with those of the sequence of Paganzo village.

2 Available data

2.1 GEOLOGICAL EVIDENCE

The main geological features of the rocks deposited in the Paganzo Basin were reported by Valencio *et al.* (1977). Briefly, a Late Carboniferous to Middle Permian age has been indicated for the rocks included in Section II of the Paganzo Group; an Illawarra Zone age (Late Tatarian–Early Scythian and younger, but older than Middle Triassic), was suggested for the Amaná–Talampaya rocks.

The sequence of Paganzo rocks included in this study (Mina Las Mellizas, 30° S 67° W, Fig. 1) has been assigned to La Colina Formation which is correlated with Section II of the Paganzo Group (Morelli 1967 and Azcuy & Morelli 1970). These rocks have been further divided into two members termed Lower Member and Upper Member. A basaltic lava flow is exposed in the middle of the Lower Member of La Colina Formation; this is the same lava flow exposed at Las Torres and dated by Thompson & Mitchell (1972) at 295 ± 5 Myr. The red beds included in the Amaná–Talampaya Formation rest unconformably on La Colina rocks.

2.2 THE PALAEOMAGNETIC STUDY

Red sediments and the basaltic lava flow from La Colina Formation and red beds from the Amaná–Talampaya Formation were collected along two profiles situated near Mina Las Mellizas (Fig. 1). Rocks from the Lower Member of La Colina Formation and the Amaná–Talampaya Formation were sampled along the profile A–B situated to the north-east of Mina Las Mellizas near Portezuelo de la Cuesta. Sediments from the Lower and Upper Members of La Colina Formation were collected along the profile C–D situated to the north-east of Mina Las Mellizas near Las Torres. Sampling started from the lowest exposures of La Colina Formation in the area and extended up to the highest exposures of the Amaná–Talampaya, covering a sequence of about 300 m. Hand samples were collected at stratigraphic intervals of 2–8 m.

Sixty-eight hand samples were collected from La Colina Formation (58 from the Lower Member and 10 from the Upper Member) and 33 samples from the Amaná–Talampaya Formation. Eighteen observations of the bedding plane were carried out (Table 1).

Table 1. Summary of bedding plane observations of the La Colina/Amaná–Talampaya sequence situated near Mina Las Mellizas.

Formation	Bedding plane				
	N	Strike (°)	Dip (°)	α_{95} (°)	k
Amaná–Talampaya	10	52	13	5	83
La Colina	8	1	18	9	35

Detailed thermal cleaning was used to isolate the stable remanence of the sediments (Valencio *et al.* 1977). The optimum demagnetizing temperature varied between 250 and 300°C at which more than 60 per cent of the natural intensity was retained. The blocking temperatures covered the range from 400 to 600°C. Sediments were also submitted to chemical leaching in which the specimens were immersed in hydrochloric acid (8N) for a given time (8, 31, 107, 270, 470, 700, 990 and 1300 hr), washed in water, measured and then reimmersed in acid (Roy & Park 1974). The leaching rate was optimized by cutting two incisions in each specimen. The optimum demagnetizing chemical leaching time was 700 hr, at which more than 50 per cent of the natural intensity was retained. No substantial differences between the directions of the stable remanence isolated during the thermal and chemical cleaning were observed, (Fig. 2).

The stable remanence of the basaltic lava flow and the underlying baked sedimentary rocks were isolated by detailed alternating field demagnetization. The optimum demagnetizing AC field was 200 Oe at which more than 80 per cent of the NRM intensity was retained.

Three samples from the Amaná–Talampaya Formation showed anisotropic RM; it was not possible to isolate stable remanence in these samples.

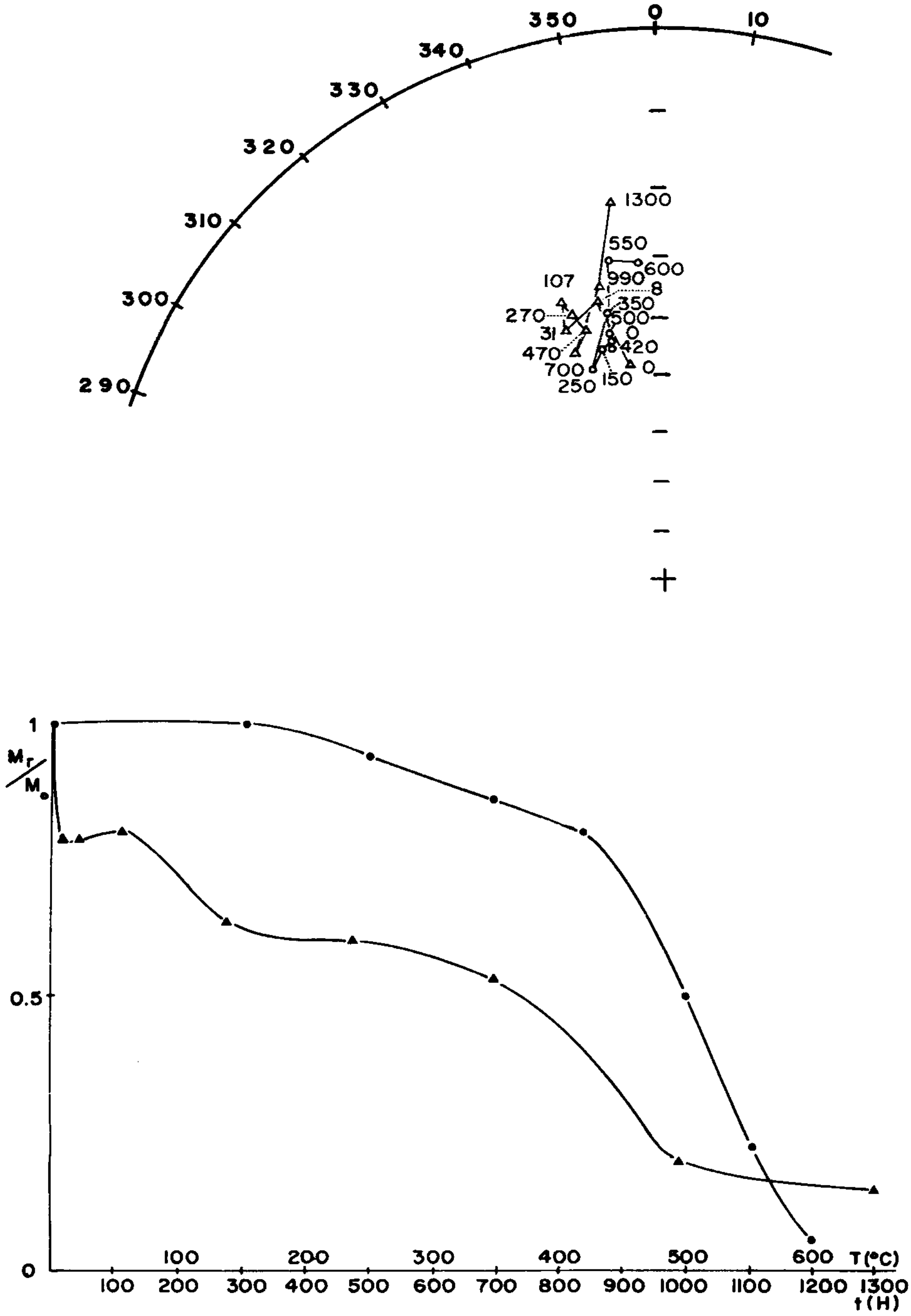
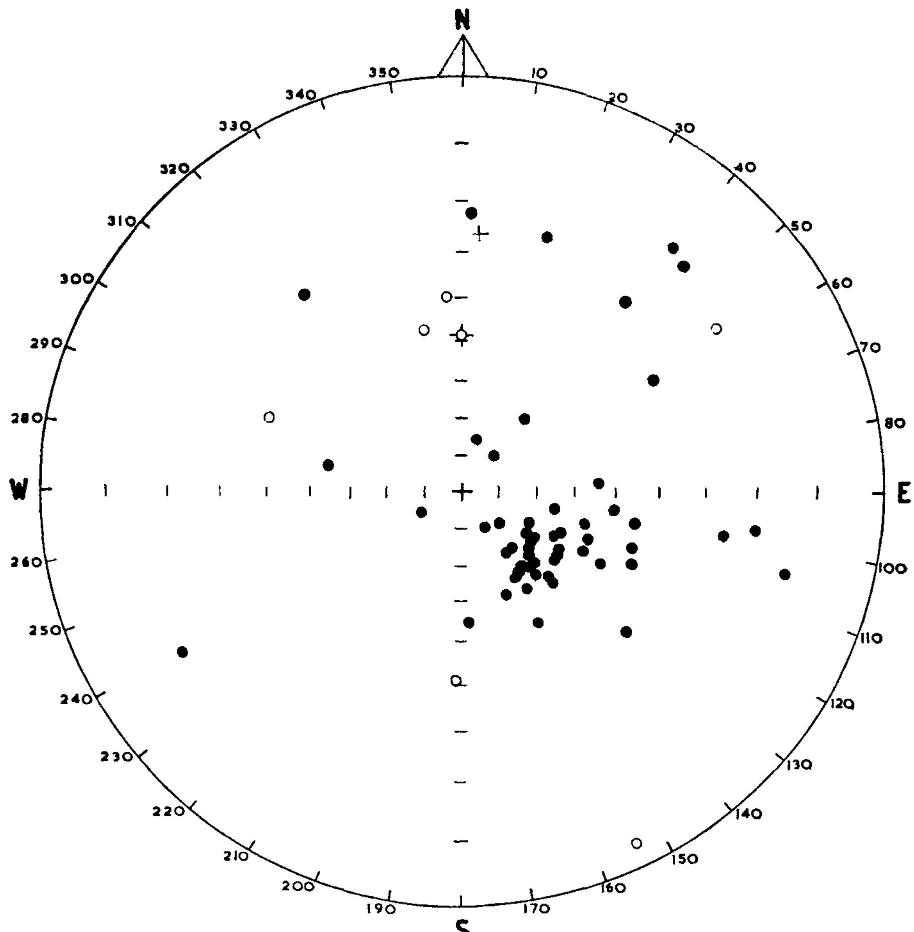


Figure 2. Mina Las Mellizas, La Colina Formation. Changes in direction and intensity of specimens in response to thermal cleaning (o) and chemical leaching (△). Open symbols indicate upward dipping directions. The specimens belong to one of the hand samples which defines the normal polarity event at the base of the sequence (Fig. 5).

Table 2. Summary of palaeomagnetic results of the La Colina/Amaná–Talampaya succession exposed near Mina Las Mellizas.

Formation	Natural remanent magnetization referred to the palaeohorizontal					Cleaned remanent magnetization referred to the palaeohorizontal					Palaeomagnetic pole			
	N	D (°)	I (°)	α_{95} (°)	k	N	D (°)	I (°)	α_{95} (°)	k	Latitude (°) S	Longi-tude (°)E	$d\chi$ (°)	$d\psi$ (°)
Amaná–Talampaya	30	176	5	21	2	30	170	−6	21	3	55	94	21	11
La Colina	68	116	65	8	6	68	129	59	6	9	48	356	9	7



(a)

Figure 3. Mina Las Mellizas, La Colina Formation. Directions of (a) NRM and (b) cleaned RM of hand samples after bedding plane correction. Solid symbols indicate downward dipping directions. The directions of the present geomagnetic field and the axial dipole are shown by + and ⌖ respectively.

Sample – mean directions (Fisher 1953) of NRM and stable RM were referrred to the palaeohorizontal; however, the fold test could not be applied because all the samples come from one area where the dip of the strata is uniform (Table 1).

The mean directions, after bedding plane correction, of NRM (a) and stable RM (b) of each sample from La Colina and the Amaná–Talampaya Formations are shown in Figs 3 and 4, respectively. The mean directions, referred to the palaeohorizontal, of the NRM and stable RM of the 68 hand samples from La Colina Formation and the 30 samples from the Amaná–Talampaya Formation are given in Table 2.

3 Interpretation of results

Composite logs of sample – mean values of stable declination (D) and inclination (I) are plotted alongside the lithologic log in Fig. 5. The character of variations in D and I in the

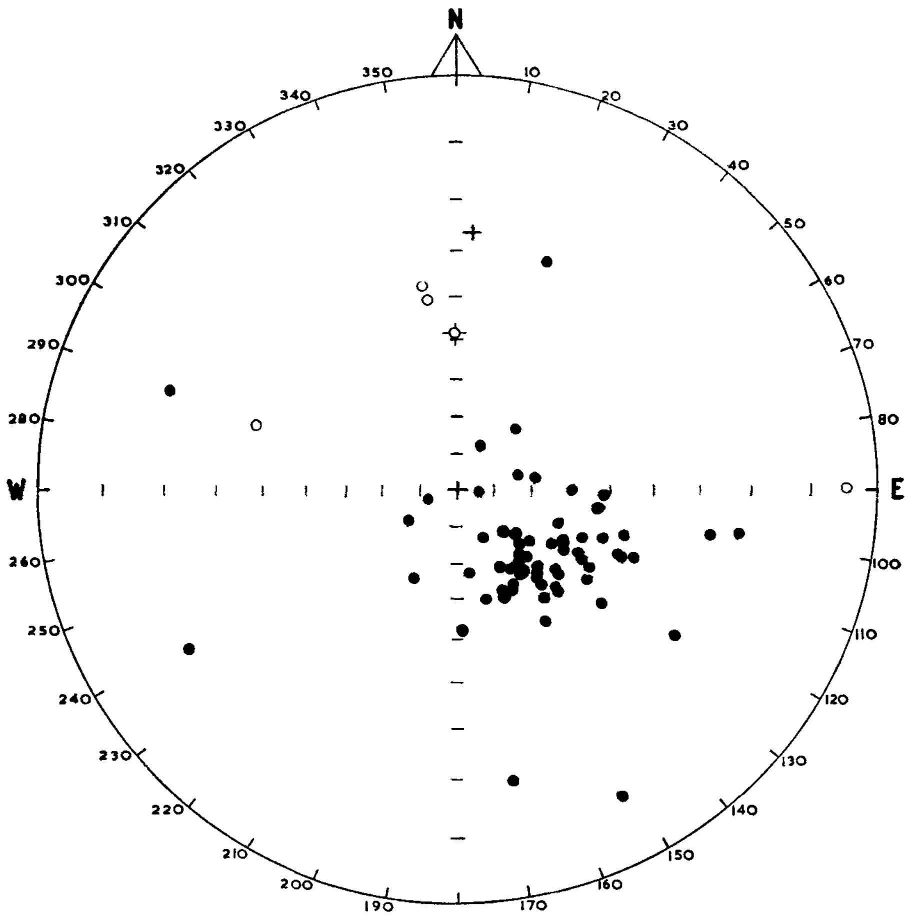


Figure 3(b)

Amaná–Talampaya Formation differs from that in La Colina Formation where these parameters undergo relatively small oscillations around 120 and 65° respectively. This quiet behaviour of an oscillating reversely polarized geomagnetic field holds throughout La Colina Formation except at the base of the sequence where northerly declinations and negative inclinations are recorded. In contrast, in the Amaná–Talampaya Formation frequent reversals of both declination and inclination are recorded.

We use a 40° cut-off to classify the sample-mean virtual geomagnetic poles (Valencio *et al.* 1977). The populations of VGPs within 40° of the mean pole for each formation give mean pole positions for La Colina and the Amaná–Talampaya Formations at 49° S 343° E (SAC_4, $N = 57$, $k = 16$, $\alpha_{95} = 5°$) and 63° S 96° E ($N = 14$, $k = 14$, $\alpha_{95} = 11°$), respectively. The rejected VGPs are classified as oblique. We interpret an observed sequence of oblique VGPs as indicating a short polarity event within a succession of rocks of a given magnetic polarity, if in the limit at least one VGP lies within 40° of the pole of opposite polarity. In this way the normal polarity events E (La Colina Formation) and F, G, H, I, J and K (the Amaná–Talampaya Formation) are defined. The other sequences of oblique VGPs are interpreted as records of geomagnetic excursions, labelled δ and ϵ (La Colina Formation) and ξ, θ and κ (the Amaná–Talampaya Formation).

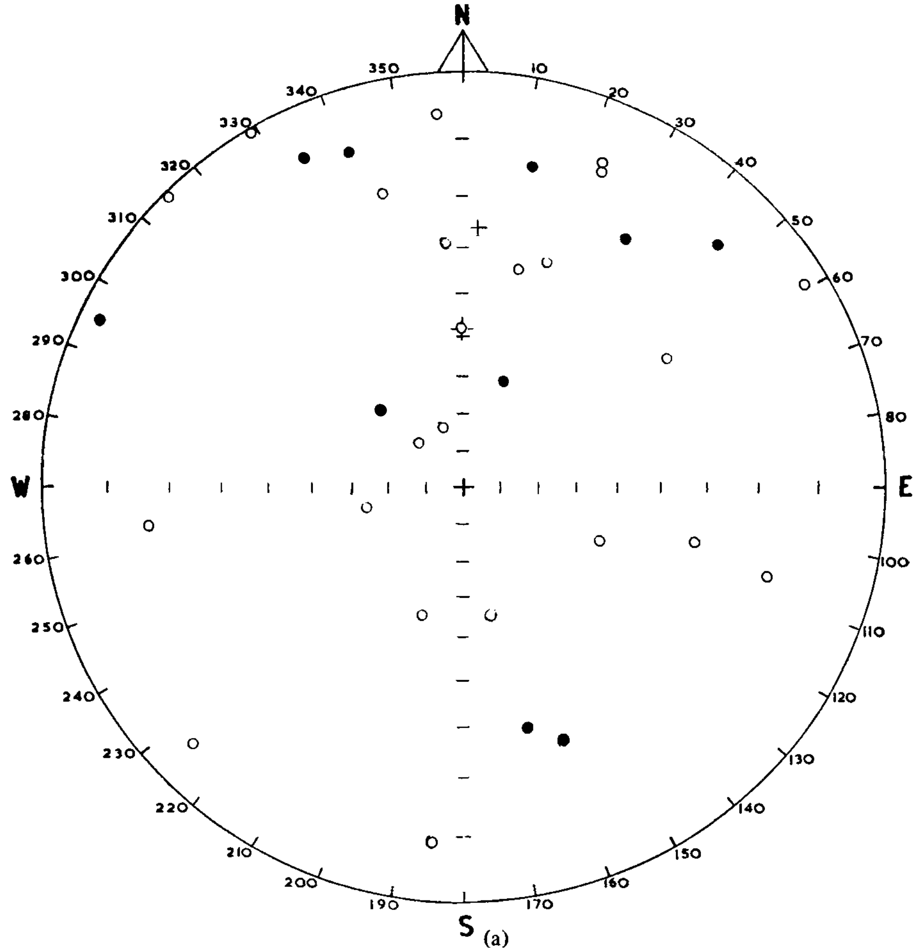


Figure 4. Mina Las Mellizas, Amaná–Talampaya Formation. Directions of (a) NRM and (b) stable RM of hand samples referred to the palaeohorizontal. For symbols, see Fig. 3.

The position of the palaeomagnetic pole we have computed for La Colina Formation exposures near Mina Las Mellizas is close to the positions of the Late Carboniferous palaeomagnetic poles for the Piaui Formation (SAC_1, Creer 1965) and the Tubarâo Group (SAC_3, Valencio, Rocha-Campos & Pacca 1975), Fig. 6. It is also close to the positions of the palaeomagnetic poles for La Colina Formation exposures near Huaco (SAP_4) and Los Colorados (SAP_3) and for the Paganzo Group ($SAPC_1$) for which a Late Carboniferous age has been suggested (Valencio 1972). This is consistent with the K–Ar age (295 ± 5 Myr, Thompson & Mitchell 1972) obtained for the lava flow situated within La Colina rocks succession involved in this study. Therefore, it is reasonable to accept a Late Carboniferous age for La Colina rocks exposed near Mina Las Mellizas. If this is the case, the short polarity event recorded at the base of the succession should be correlated with the latest of the normal events which define the Debal'tseva Zone (Fig. 5).

The mean position of the Late Carboniferous palaeomagnetic poles for South America is 60° S 353° E (SACu, $N = 6$, $k = 153$, $\alpha_{95} = 5°$, Fig. 6).

The magnetic stratigraphy for the Amaná–Talampaya sediments exposured at Mina Las Mellizas is similar to that for the Amaná–Talampaya succession exposed near Paganzo

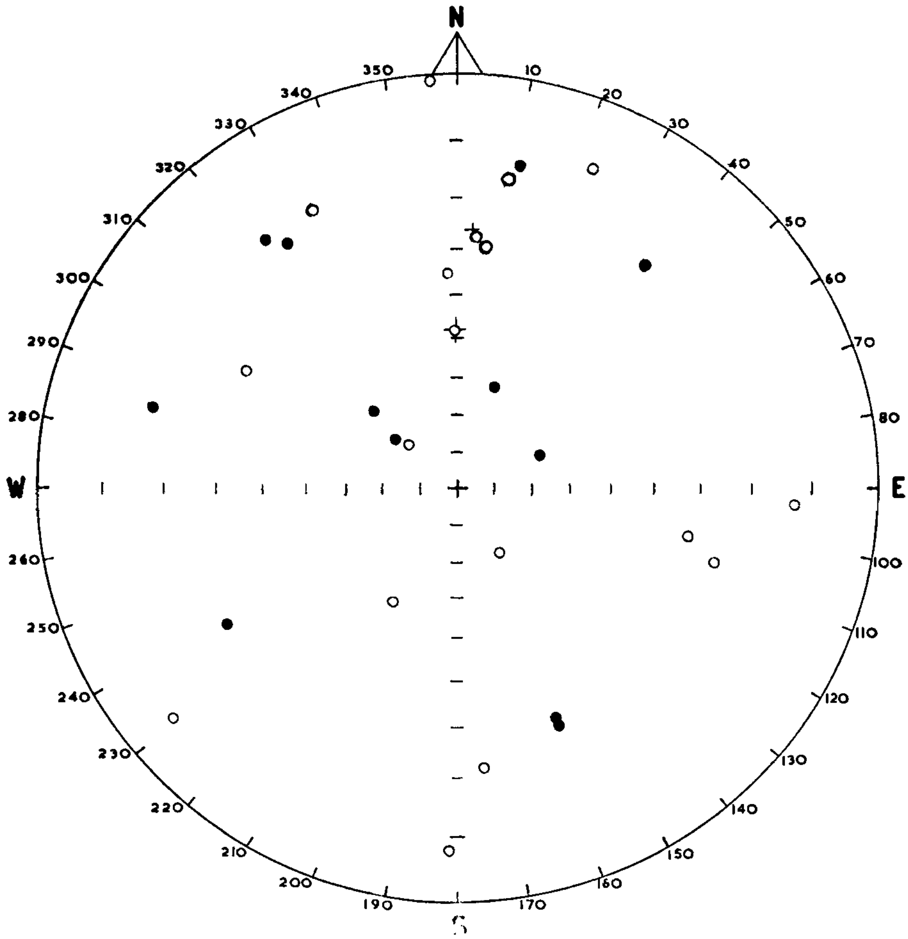


Figure 4 (b)

village (Valencio *et al.* 1977) which has been assigned to the Illawarra Zone (Late Tatarian–Early Scyntian and younger, but older than Middle Triassic, Fig. 5). They are characterized by frequent reversals of both *D* and *I* which are associated with short-lived polarity transitions or with geomagnetic excursions. The only difference is that a period in which the geomagnetic field was in steady state of reversed polarity is recorded in the Paganzo village succession. In the Mina Las Mellizas succession such a period is not recorded. Therefore, it seems to us that the position of the palaeomagnetic pole computed from our palaeomagnetic data for the Amaná–Talampaya sediments exposed near Mina Las Mellizas does not represent the real position of the palaeomagnetic pole for South America in Illawarra time being affected by the frequent reversals of the geomagnetic field.

Fig. 5 shows the correlation of the magnetic stratigraphy for La Colina and the Amaná–Talampaya Formations exposed near Mina Las Mellizas with the schematic section of the Kiaman Magnetic Interval and the Debal'tseva and Illawarra Zones. This interpretation and that presented by Valencio *et al.* (1977) for palaeomagnetic data from rocks of the same formations exposed near Paganzo village indicate that the history of the Paganzo Basin is more complicated than that accepted heretofore.

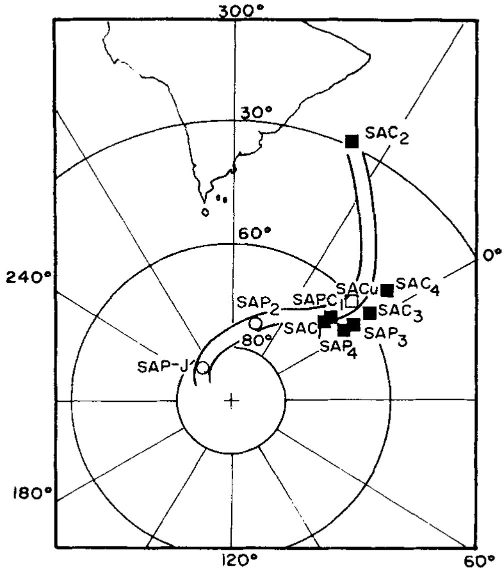


Figure 6. Late Carboniferous palaeomagnetic poles (□) for South America. SAC_4 is the palaeomagnetic pole for La Colina Formation rocks exposured near Mina Las Mellizas. Other references in the text. Solid symbols indicate reversed remanence. SACu is the mean of the Late Carboniferous poles. The Late Palaeozoic section of the polar wandering curve for South America (Valencio *et al.* 1977) is also illustrated.

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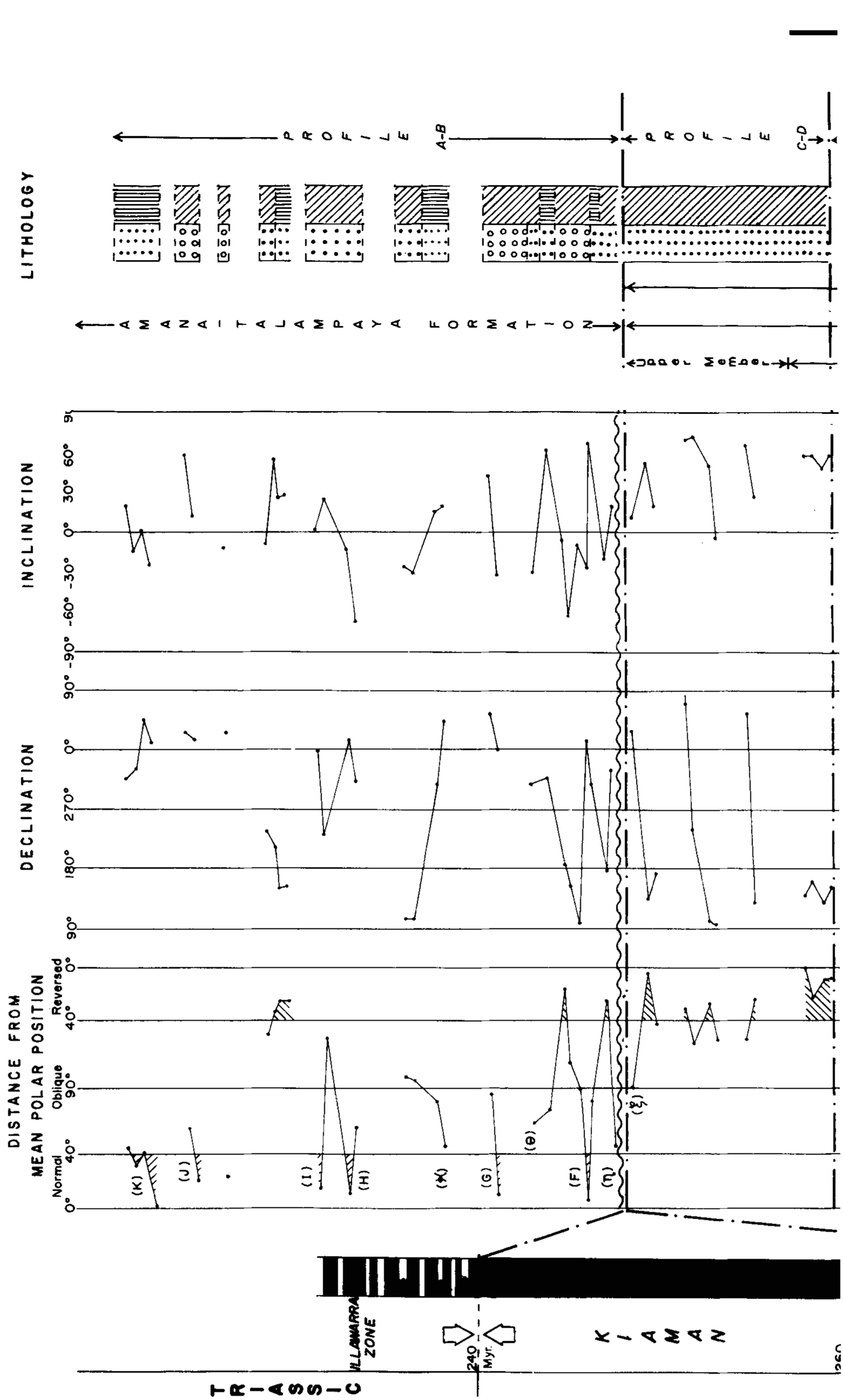
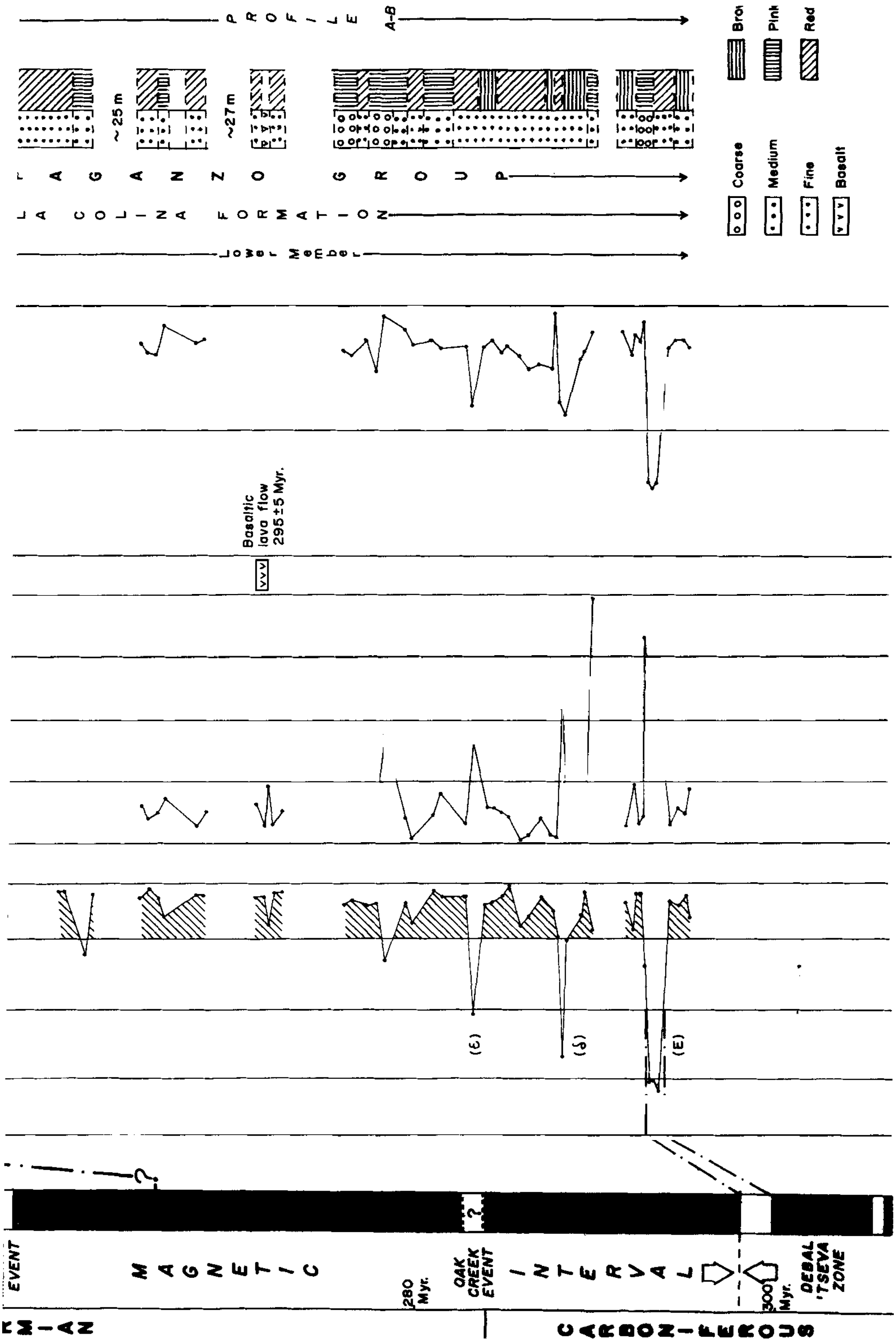


Figure 5. Mina Las Mellizas. Declination and inclination of the stable RM and the angle between th
The lithologic column and the schematic composite section of the Kiaman Magnetic Interval (Valenci



ɜP for each hand sample and the mean pole through La Colina and Amaná–Talampaya Formations.
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